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Inventor : Sivarama K. Kuchibhotla et al.
Title : **ILLUMINATION COMPENSATOR FOR CURVED SURFACE LITHOGRAPHY**

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SECTION B –Amendments to the specification:

(Page 5 , Fourth Paragraph)

Another object of the invention is to permit scanning projection imaging, by providing an effective solution for beam coupling mechanism using an innovative optical system ~~called~~ '~~Zerogon~~ zero-power meniscus lens pair that carries the curved mask on one of its surfaces.

(Page 5 , Fifth Paragraph)

Another innovative feature of the invention is to provide a unique design for ~~Zerogon~~ zero-power meniscus lens pair by means of a symmetric arrangement of two identical meniscus optical elements so that it works as a null compensator for collimated or converging beams interacting with a curved mask and thus causing negligible deviation or shift of the beam passing through such a device.

(Page 6 , First Paragraph)

An advantage of such unique configuration for ~~Zerogon~~ zero-power meniscus lens pair is that the design could be scaled up to conduct large-area curved patterning with relatively smaller cross-section of scanning convergent beam imaging on one of its outer surfaces thus facilitating large-area seamless scanning for curved –curved lithography.

(Page 6 , Third Paragraph)

Figure 1 is a simplified semidiagrammatic elevation view of a preferred embodiment of the invention, showing a compensated curved mask with ~~Zerogon~~ zero-power meniscus lens pair and curved substrate that lead to an effective beam coupling,

(Page 7 , Second Paragraph)

Figure 7 is a PRIOR ART diagram showing how the conventional lens pair called the "Hypergon" acts as an imaging system and is significantly different from ~~Zerogon~~ zero-power meniscus lens pair, in construction and performance.

(Page 7 , Third Paragraph)

Figure 8 is a diagram showing how a lens pair, such as the ~~Zerogon~~ zero-power meniscus lens pair, transmits the light beams without any deviations, and hence can provide an effective coupling of the illumination beam to the projection lens.

(Page 7 , Fourth Paragraph)

Figure 9 is an unfolded diagram showing how the ~~Zerogon~~ zero-power meniscus lens pair, mask combination helps the projection lens collect the necessary diffraction orders.

(Page 7 , Fiftth Paragraph)

Figure 1 and Figure 2 show the preferred embodiment for patterning onto curved substrates by using a ~~Zerogon~~ zero-power meniscus lens pair 1, mask 2 having a curvature that is identical to that of the substrate 3 (i.e., the size and shape of the mask 2 and substrate 3 are the same) by additionally

performing the imaging using a 1:1 projection imaging system featuring reverser 4, projection lens 5, and fold mirrors 6 as required in directing the patterning beam from illumination source 7 to substrate 3. Stage 8 provides scanning motion. All elements of Figure 2 (PRIOR ART) are also present in Figure 1. The difference between the system of Figure 1 and the PRIOR ART system of Figure 2 is the presence of the ~~Zerogon~~ zero-power meniscus lens pair 1, in Figure 1 and the absence of the ~~Zerogon~~ zero-power meniscus lens pair 1, in Figure 2. The ~~Zerogon~~ zero-power meniscus lens pair 1, in Figure 1 provides an effective beam coupling between the curved mask and the projection lens.

(Page 16 , First Paragraph)

~~Zerogon zero-power meniscus lens pair~~ :

The Goerz Hypergon lens (U.S.Patent 706,650-~~1902~~), a traditional photographic objective, consists of two symmetrical menisci equidistant on either side of the aperture stop. The inner and outer radii of curvature of the Goerz Hypergon differ by only one-half percent, producing a very flat Petzval curvature even at very large field of view. The aperture stop between the menisci is important in the Goerz Hypergon lens; this arrangement generates lens power as shown in Figure 7. However, in the current application we need to project the condensed beam onto a curved surface of an optical system, which on refraction would not deviate the beam. This calls for a zero-power optical system, the outer surface on which the converging illumination beam is in focus, scans the curved surface with the help of unitary stage. In other words, we need to consider an optical system with diameter larger than the scanning beam. The purpose of such an optical device is not to deviate the transmitted beam on exit. This can only be achieved by transmitting the beam through a zero-power optical device as that of a plane parallel plate. In this section, we discuss the design and function of such a device that we will call ~~Zerogon~~ zero-power meniscus lens pair 1,. The ~~Zerogon~~ zero-power meniscus lens pair 1 has an outer curved surface and would not deviate nor shift the beam laterally on transition. In the current application, the outer curved surface of the ~~Zerogon~~ zero-power meniscus lens pair 1 carries the curved mask 2.

(Page 17 , First Paragraph)

The ~~Zerogon~~ zero-power meniscus lens pair 1 has two identical menisci with their radii of curvature set by Eqn. (9) and the elements grouped in close proximity, with their concave surfaces facing each other as shown in Figure 8. The outer surface holds the flexible mask 2 close enough using a locking band 9. The goal of designing such an optics device is to make the small-sized illuminating beam transmit through the optic at any height from the optical axis of the ~~Zerogon~~ zero-power meniscus lens pair 1, without any deviation or shift to preserve the concept of providing constant partial coherence factor for the sake of obtaining better resolution and contrast in curved mask lithography. As proved in this section, the symmetry of the configuration cancels out the lateral shifts introduced by each meniscus without deviating the ray through the system and thus preserving the numerical aperture of the condenser and resolution characteristics of the projection system. Notice that the lookalike Hypergon on the other hand, is an imaging system as shown in Figure 7, with construction and performance significantly different from that of the ~~Zerogon~~ zero-power meniscus lens pair 1. Figure 7 shows how the Hypergon of PRIOR ART has lens power. Figure 9 shows how the placement of the mask 2 on the convex exit surface of the ~~Zerogon~~ zero-power meniscus lens pair 1, with the focus on the curved mask 2, allows for proper focus of the projected beam onto the curved substrate 3.

(Page 17 , Second Paragraph)

We may now extend the above raytracing equations to ~~Zerogon~~ zero-power meniscus lens pair 1. In order to work out a ~~Zerogon~~ zero-power meniscus lens pair 1, let us consider a lens doublet of two identical menisci with concave surfaces facing each other. Let us assume that the second meniscus element, separated from the first meniscus by a distance t_2, has radii of curvature R_3 and R_4 and thickness t_3. The transfer equation to third surface may now be written as

(Page 18 , First Paragraph after all formulas)

Thus a ~~Zerogon zero-power meniscus lens pair~~ would not cause any shift in the height of the axial ray unlike a single meniscus lens. Now, let us see the deviation of a ray produced by the device.

(Page 19 , Paragraph at mid-page, after Formula 15)

It is now easy to explain how Eqn.(9) could help a ~~Zerogon~~ zero-power meniscus lens pair 1 achieve the function of the required illumination compensator without deviation and shift of a ray. When Eqn.(9) is satisfied, Eqn.(15) can be simplified to

(Page 19 , Paragraph at bottom-page, after Formula 16)

The ~~Zerogon~~ zero-power meniscus lens pair 1 worksheet below illustrates the calculations for a sample ~~Zerogon~~ zero-power meniscus lens pair 1, worked out for an outer radius of curvature of R = 50 mm and thickness of 10 mm. The calculations were done for a displaced axial ray and an off-axial ray entering the lens with an angle. Initially it is required to compute the inner radius of curvature of the meniscus elements for a given value of radius on the outer surface using Eqn. (9) and then the above set of equations or any standard optical design software can be used to evaluate the design. The paraxial

raytrace values of a given ray as given in the table may be compared with the real raytrace values that fall in close agreement with each other.

(Page 20 , Paragraph at bottom-page, after Worksheet)

It may be seen that the ~~Zerogon~~ zero-power meniscus lens pair 1 preserves y_i , u_i , and u'_{pi} of any given ray on first and fourth surfaces, having the same functional properties as that of a plane parallel plate. In fact, it is easier to prove and visualize the ~~Zerogon~~ zero-power meniscus lens pair 1 as equivalent to a pair of plane parallel plates separated by the same distance as that of menisci in ~~Zerogon~~ zero-power meniscus lens pair 1. The optical path length variation for any arbitrary ray in meniscus elements is compensated by the altered air path between the menisci.

(Page 21 , First Paragraph)

An application of the ~~Zerogon~~ zero-power meniscus lens pair 1 is its use at intermediate curved image surfaces with the image surface falling on ~~Zerogon~~ zero-power meniscus lens pair 1's outer surface whose radius of curvature could be designed to the field curvature of the optics in front of the ~~Zerogon~~ zero-power meniscus lens pair 1. The description and example above emphasize its behavior equivalent to that of a plane parallel plate with curved surfaces. Hence, wherever a plane parallel plate has to be replaced by an optic with curved surfaces, the ~~Zerogon~~ zero-power meniscus lens pair 1 could be used without affecting the performance of whole system.

(Page 21 , Second Paragraph)

Use of ~~Zerogon~~ zero-power meniscus lens pair 1 *for curved lithography.*

As described earlier, the illuminated beam from the condenser could be effectively coupled to the projection lens by resting the curved mask on an optical device that transmits the beam undistorted. A ~~Zerogon~~ zero-power meniscus lens pair 1, with its outer radius of curvature to match with that of the substrate and a membrane mask, that is proprietary to Anvik technology, will be precisely stretched and secured over the outer surface by a frame to fix its position. The ~~Zerogon~~ zero-power meniscus lens pair 1-curved mask combination works just like that of a planar mask providing an efficient coupling between

illumination system and the imaging system for curved lithography. Figure 9 is a schematic of the functionality of the ~~Zerogon~~ zero-power meniscus lens pair 1 / mask combination and how the necessary diffraction orders are collected by the projection lens.

(Page 22, Second Paragraph)

We discussed a novel optics device, called ~~Zerogon~~ zero-power meniscus lens pair 1, that has curved optical elements exhibiting zero total power and performs as good as a plane parallel plate causing no deviations to the incoming radiation. Having this unique null property ~~Zerogon~~ zero-power meniscus lens pair 1 is expected to serve various applications as an alternative to plane parallel plate. We also use the ~~Zerogon~~ zero-power meniscus lens pair 1 with curved mask on one of its outer surfaces, making the whole device very efficient in coupling the illumination beam to the imaging system.

(Page 22, Third Paragraph)

Another important merit of this invention is that the two meniscus elements can also be arranged back-to-back on convex surfaces with concave outer surfaces and make the device still carry the same properties described above for ~~Zerogon~~ zero-power meniscus lens pair 1. Hence either configuration could be referred to as part of the present invention.